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Evaluation of UNILORIN Dam Moulding Sand Properties for Foundry Applications

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Abstract
The availability of suitable and cost-effective moulding sand within Nigeria is a critical requirement in foundry operations, as sand properties significantly influence casting quality, dimensional accuracy and surface finish. Evaluation of moulding sands properties in Nigeria is key in determining their usefulness for foundry practices. In developing countries, foundries often depend on imported sand due to uncertainty about local materials, with rise in production costs and hindering local industry sustainability. The University of Ilorin Dam may provide a viable source of sand for foundry moulding, but there is insufficient scientific data on its crucial engineering properties that is needed to assess its suitability for metal casting. In this research, the chemical and physico-mechanical properties of Unilorin dam natural moulding sand were evaluated to determine its suitability for foundry operations using America Foundrymen's Society standards. The experimental results showed that the sand belong to Alumino-silicate group containing silica (58.621%) and alumina (14.074%), with smaller proportions of other alkali elements such as sodium dioxide, potassium dioxide, lime, iron oxide, magnesia and titanium dioxide. The sand exhibited clay content (4.98%), moisture content (0.68%), grain fineness number (63.91), green compressive strength (87.29 KN/m²), dry compressive strength (234.02 KN/m²), specific gravity (2.56), shatter Index (73.03%), bulk density (2306.46 kg/m³), permeability (0.005330 cm/sec) and refractoriness (>510°C). Most of these results were within the AFS standard recommendation values for non-ferrous metal casting. Hence, Unilorin dam natural moulding sand was found suitable as moulding sand for various types of casting of metals like light grey iron, aluminum, bronze, brass. The sand is also suitable for manufacturing of ceramics, refractory products, or possibly as a raw material for pozzolanic materials. Effective utilization of this sand for foundry applications will help to boost the economy of the Nation and subsequently aid in reducing the problem of unemployment.

Keywords: *Foundry, Casting, Unilorin dam sand, Chemical Analysis, Physico-mechanical properties.*

1.0 Introduction

Foundry is one of the oldest manufacturing processes which involves the melting of metals, ferrous and ferrous metals and pouring them into the mould cavity prepared by the moulding sand to produce a durable and marketable casting product with good mechanical and physical properties which are economical and cost effective to the development of a country [1], [2].

Foundry gives raw casting and parts to most enterprises and industries in the agricultural nations which makes foundry to be the mother of all remaining industries. Foundry don't simply deliver raw castings, they house various tasks like casting of various apparatus for building, model, machining, and other after-deal operations and on these grounds, foundry innovation has become imperative [3]. One of the old techniques for metal shaping is casting in foundry which some of the steps in casting involve preparation of mould, liquefying of metals, filling the mould with molten metal, hardening, shake-out and fettling. This process is use for most of all type of casting like investment casting, centrifugal, die casting and sand casting, among others [4]. Sand casting, otherwise called sand moulded casting, is a metal casting categorically described by utilizing sand as the form material [5].

Sand casting is one of the most well-known and easiest sorts of cast and not only does this technique permits manufacturers to make items for a minimal price, it also has different advantages like reusability, wide adaptability, and casting of different shapes are achievable [6]. The green sand contains 85–95% of silica sand, 7–10% binder, around 5% coal residue, and 2–5% water. Silica sand is the significant element of sand shape for ferrous and non-ferrous casting [7]. World-wide attention has been drawn to green sand mould castings because the types of processing gears and equipment, raw materials accessibility (silica sand bentonite) and moulding materials reclaimability. The moulding sand properties are affected by type (zircon or silica), shape and size of sand, curing time, kind of binder and additives added to it [8].

Moulding sand is one of the most important materials needed in foundry technology for making moulds, the quality of the casted product greatly depends on the characteristic constituents of the moulding sand used, the properties of these constituents, and occasionally even the nature of the additives used to enhance the properties of the moulding sand [9]. The main constituents of moulding sand include silica sand, binder/clay and moisture. The silica sand grains play a crucial role in shaping sand because they give it properties including refractoriness,

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chemical resistance, and permeability. The closer the contact will be and the lower the permeability, the finer the sand grains will be [10], [11]. Binders can be either organic or inorganic, clays like kaolinite, limonite, ball clay and bentonite amongst others also act as binders for moulding sands with the aid of moisture and are used to impart strength and cohesiveness to the moulding sand [12].

Local foundries in different parts of Nigeria frequently use improper moulding sands for a range of casting operations without first examining the sand's characteristics and suitability for that casting operation. This necessitates that researchers in this field assess these moulding sands for appropriate grading, a sufficient amount of clay content, and an optimal amount of water to be added in order to yield good casting products. Also, there is a need to look into the effects of various additives on the chemical and physico-mechanical properties of the moulding sand, which determine the characteristics of the casting produced [9].

This study evaluates the suitability of moulding sand obtained from the University of Ilorin Dam for foundry applications. Sand samples were collected and subjected to standard laboratory tests to determine key properties such as grain size distribution, permeability, green compressive strength, moisture content, clay content, and refractoriness. The experimental procedures followed established foundry testing standards to ensure reliability of results. The obtained properties were compared with standard requirements for quality moulding sand used in metal casting. The analysis aimed to identify the strengths and limitations of the sand in practical foundry operations. Results were interpreted to assess its performance in terms of casting quality, surface finish, and defect minimization. The study ultimately determines whether the sand can be utilized directly or requires modification for optimal foundry use. Thus, material and financial wastages as results of casting defects in production of intricate parts and other devices would be drastically minimized in the foundry practice. Overdependence on importation of foundry sand and its products into Nigeria will be drastically reduced, if not totally stopped.

2.0 Materials and Methods

2.1 Materials

2.1.1 Area of study

This study evaluates the suitability of moulding sand obtained from different locations around the University of Ilorin Dam for foundry applications. Sand samples were collected from multiple sites near the dam to account for possible variation in properties with the coordinates of 8^{o} 28'00.9" N (latitude), 4^{o} 39'7" E (longitude) [13].

2.2 Determination of chemical composition

The elemental chemical contents of the moulding sand produced from Unilorin dam site were analysed using X-Ray Fluorescence. The analysis was performed at the National Geoscience Research Laboratories Centre in Kaduna, Nigeria, in accordance with established methodology following AFS 5222-13-S standard criteria. The prepared sample of Unilorin dam moulding sand was precisely weighed and positioned in a metallic sample container. The sample holder was then placed into the X-Ray apparatus for a period of 2 minutes. Subsequent to this interval, the analysis results were exhibited on the monitor linked to the X-Ray Fluorescence Spectrometer apparatus.

The elemental chemical composition of the prepared moulding sand obtained from the University of Ilorin dam was determined using X-ray fluorescence (XRF) analysis. The analysis was carried out at the National Geoscience Research Laboratories Centre, Kaduna, Nigeria, in accordance with established procedures adopted by previous researchers [14] and in compliance with the AFS 5222-13-S [15] standard guidelines.

For the analysis, an accurately weighed sample of the prepared moulding sand was placed into a metallic sample holder, which was then introduced into the XRF spectrometer and analyzed for a duration of two minutes. The elemental composition results from the analysis were automatically displayed on the monitor connected to the XRF equipment.

2.3 Specimen preparation

Standard test specimens were created following the guidelines of the American Foundry-Men Society (AFS) to assess the physico-mechanical properties of molding sands, which are essential for determining it suitability for foundry practice. The process involved passing silica sand through a standard sieve with a 1.80 mm aperture to eliminate larger silica grains and ensure a reasonably uniform grain size. Subsequently, using a Compacting Machine/Sand Ramming Machine, the prepared sand samples were shaped into cylindrical standard test specimens of 50 mm by 100 mm and compacted using a sand compactor machine delivering 60 blows, and then removed from the mould in accordance with AFS 5222-13-S [15] standards and BS 1377: Part4 [16].

2.4 Physico-Mechanical Properties Tests

The physico-mechanical properties of the blended naturally moulding sands samples were determined to assess the moulding sand suitability for foundry applications using standard procedures specified by the American

Foundry Society (AFS). This focuses on the sand's physical behaviour and mechanical strength. Key evaluations included grain size distribution to analyze particle size, moisture content for bonding strength and plasticity, and permeability to allow gas escape during casting. Additionally, tests for clay content measured binder levels affecting cohesiveness, while green and dry compressive strength tests gauged sand's ability to withstand handling and molten metal pressure. Lastly, refractoriness tests determined high-temperature resistance. These tests collectively ensure the production of defect-free castings and compliance with foundry standards.

2.4.1 Grain Fineness Number

The grain fineness number of the prepared silica sand was assessed using a Mechanical Shaker (Endocoil Test Sieve Shaker; Voltage: 220/240; Phase: Single; Frequency: 50; Current: AC 1.8) along with mesh sizes 8, 10, 16, 22, 60, 100, 150, and 200, a set of British sieves, and an electronic weighing balance. Freshly prepared AFS samples consisting of 1000 g of silica sand, previously cleaned and sun-dried to remove moisture content, were weighed using the electronic balance, and the weight was recorded. Subsequently, the set of British sieves was arranged from largest to smallest aperture, including a pan. The initially measured 1000 g of silica sand was gently poured from the top sieve into the stack of sieves. The entire set of British sieves, along with the weighed silica sand, was placed on the mechanical shaker, which was then activated to vibrate for approximately 15 minutes. After this duration, the mechanical shaker was turned off, and the stack of sieves was removed from it. The amount of silica sand retained in each sieve was weighed, and their respective weights were recorded using the electronic weighing balance. This method was carried out using the guidelines in the relevant standards for foundry [17],[18], [19], [20], [21], [22], [23].

Utilizing these parameters, the AFS Grain Fineness Index was calculated using the Equation (1) [16].

$$The\ AFS\ Grain\ fineness\ number = \frac{W}{\sum S_r\%} \quad (1)$$

where: $W = Total\ Weight\ of\ the\ product$; $\sum S_r\% = Total\ sum\ of\ percentage\ of\ sand\ retained\ by\ diffent\ sieves$

2.4.2 Moisture Content

Samples of the moulding sand were weighed and then transferred into clean, identical aluminium cans. The empty aluminium cans were weighed separately to determine their weight, recorded as W_1, using an electronic balance. Subsequently, the aluminium cans containing the pre-weighed sand samples were placed on the electronic balance, and their combined weight was measured and noted as W_2. Next, these cans, with the sand samples inside, were subjected to a controlled temperature of 110°C in an oven for approximately 24 hours. After this drying period, the sand samples were removed from the oven, and their weight was recorded as W_3. This procedure was done in accordance with the guidelines in AFS 2218 – 00 Standard. The moisture content was calculated using the relationships in equation (2) [12].

$$Mositure\ content = \frac{W2-W3}{W3-W1} \quad (2)$$

Where, W_1 = Weight of the aluminium can, W_2 = Weight of the aluminium can and sand sample before drying, W_3 = Weight of the aluminium and sand sample after drying, $W2 - W3$ is the loss in weight of sand (g), and $W3 - W1$ is the weight of the sand sample taken (g).

2.4.3 Clay content

The clay content was determined by measuring the weight loss of the sample after it was washed. In a controlled setting, a 50 g sample of pre-dried sand was taken, placed in a mixing device, and treated with a 100-concentration solution of normal sodium chloride salt (NaCl) dissolved in water. Then, the measuring cylinder with was filled with the sodium chloride solution. The sun-dried silica sand, free of moisture, was loaded into the measuring cylinder up to 200 ml capacity. Subsequently, the measuring cylinder containing the 200 ml of silica sand with the salt solution was vigorously agitated through manual shaking for approximately three minutes. This resulted in the formation of four distinct layers, separated by water, silt, clay components, and silica sand layers. Each of these layers had a volume corresponding to the calibration markings on the measuring cylinder, designated as V(water), V(silt), V(clay), and V(silica) respectively. The clay content of the moulding sand was then determined using the formula presented in Equation (3) [12,24] in line with the AFS 2110 – 04 Standard [25].

$$Clay\ content, C = \frac{V(silt) - V(clay)}{V(clay) - V(silica)} \quad (3)$$

2.4.4 Permeability

To measure permeability, a constant-head permeability meter was employed. Before conducting the permeability test, a cylindrical mass of the sand sample with predefined dimensions was prepared, following the guidelines outlined by the American Foundry Society (AFS). Subsequently, the prepared molding sand specimen was positioned within the permeability apparatus, and 2000 cm^3 of air, under a standard pressure of 9.8 x 102 N/m^2, was passed through the specimen. The time taken for this 2000 cm^3 of air to pass through was recorded using a stopwatch. The permeability value for each specimen was then calculated using Equation (4) [14]. This was carried out using AFS 5224 – 13 Standard as presented in[16].

$$Permeability\ Number, PN = \frac{V.H}{P.A.t} \quad (4)$$

PN = Permeability Number of the specimen, V = Volume of the air passing through the specimen in cm^3, H = Height of the specimen in cm, P = Pressure of the air passing through the specimen in N/cm^2, A = Cross sectional area of the specimen in cm^2 and t = The time required for the air to pass through the specimen in minutes.

2.4.5 Specific gravity

The specific gravity of the moulding sand was determined using a density bottle, vacuum desiccator, and a weighing balance. Initially, the density bottles were carefully cleaned, dried, and weighed using an electronic balance, and their weights were recorded as "M_1." Next, these bottles were filled with silica sand up to either one-third or two-thirds of their capacity, and their weights were recorded as "M_2" after filling.The density container was filled to capacity with de-aerated water to produce the moulding sand sample. After vigorous agitation, it was positioned in a vacuum desiccator for 45 minutes to eliminate any air within the sand sample. Subsequently, it was taken out, and its weight was noted as "M_3. Following these steps, the density bottle was emptied and then filled with water. The weight of the density bottle with only water was measured and recorded as "M_4." This procedure was carried out in accordance with the BS: Part 2: 7.2 Standard [25]. Finally, the specific gravity of the molding sand sample was calculated using Equation (5) [26]:

$$Specific\ Gravity, SG = \frac{M_2 - M_1}{(M_2 - M_1)(M_3 - M_4)} \quad (5)$$

where: M_1 is the mass of the empty density bottle measured in grams, M_2 = mass of the density bottle containing the prepared moulding sand, M_3 = mass of the density bottle containing both the prepared moulding sand and water and M_4 = mass of the density bottle containing only water

2.4.6 Bulk density

The bulk density of samples A and B was carried out. This determination involved transferring the moulding sand samples into measuring cylinders, followed by weighing the measuring cylinders using an electronic balance. The prepared moulding sands, which had been thoroughly sun-dried and cleaned, were then placed into 500 ml capacity measuring cylinders. Subsequently, the specimens were weighed again using the weighing balance, and this weight was recorded as the specimen's weight after the drying process. We utilized the calibration of the measuring cylinder to calculate the specimen's volume. The weights of the specimen before and after drying were denoted as W_{s1} and W_{s2}, respectively, while the volume of the specimen was recorded as V_s. With these parameters in place, we could calculate the bulk density for each of the samples using the equation described in Equation (6) [16] in line with the guidelines in BS: Part 2: 1990 Standard [14].

$$Bulk\ Density, BD = \frac{Ws1 - Ws2}{Vs} \quad (6)$$

W_{s1} = weight of the specimen before drying, W_{s2} = weight of the specimen after drying and V_s = Volume of the specimen.

2.4.7 Green and Dry strength test of the moulding sands

To determine their suitability for foundry applications, the compressive strength characteristics of the prepared moulding sand were evaluated under both green and dry conditions. The representative samples of the moulding sand were prepared by thoroughly mixing the sand with the required proportion of water at a homogenous state to ensure uniform distribution of moisture. The prepared sand samples were compacted in a specimen mould using a laboratory rammer to produce standard cylindrical test specimens with consistent density and dimensions. Necessary experimental precautions were taken to avoid segregation and ensure repeatability of specimen preparation.

The green compressive strength test was conducted immediately after specimen preparation to preserve the in-situ moisture condition. While the dry comprehensive strength test was conducted using a separate set of prepared specimens that were subjected to oven drying at a controlled temperature (110°C) for a twenty (24) hours that constant weight was achieved with total removal of moisture. The specimens were kept at room temperature in a desiccator to prevent moisture reabsorption. Both green and dried specimens were later tested for compressive strengths using the same procedures on a California Bearing Calibration (Model No.: 212060257; ELE (Engineering Lab. Equipment Ltd; Volts: 240.Amps:3, HZ.50Ph).

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2.4.8 Shatter Index Test

The standard test specimen was compacted by subjecting it to 60 blows using a sand ramming machine or sand compacting machine. Subsequently, the specimen was dried in an oven for 24 hours. After this preparation, the test specimens were dropped freely from a height of 1.83 meters onto a steel anvil. The portion of the sand samples that remained on a 12.5 mm mesh British Standard Sieve was weighed and recorded as W_s. The shatter index was expressed as a fraction percentage of the total weight of the specimen, denoted as W. The Shatter Index was then calculated using the Equation (7) [25].

$$Shatter\ Index, SI = \frac{Ws}{W} \quad (7)$$

W_s is the weight of the sand portion retained, and W is the weight of the test specimen.

3.0 Results and Discussion

3.1 Results of the Analysis

3.1.1 Results of Samples Chemical Composition

The results of chemical composition analysis for the selected Ilorin moulding sands are shown in Table 1. The XRF Analysis results, as presented in Table 1, have identified Silica (SiO_2) as the predominant constituent in both the Unilorin Dam Moulding Sand Samples, accounting for 58.621 wt.% of the sand samples. Additionally, notable compounds include Alumina (Al_2O_3), Iron (III) oxide (Fe_2O_3), Potassium oxide (K2O), and Calcium oxide (CaO), with corresponding weight percentages of 14.074 wt.%, 10.692 wt.%, 9.107 wt.%, and 2.562 wt.%. The presence of excessive iron oxide, alkali oxides, and lime can significantly lower the fusion point, which is undesirable in casting [9]. Minor traces of other alkali oxides like Tantalum (V) oxide (Ta_2O_5), Manganese oxide (MnO), WO_3, Barium oxide (BaO), Lead oxide (PbO), Copper oxide (CuO), among others, are considered impurities in the molding sand [12]. Notably, MgO was absent in the moulding sand, even though it is a significant component of the clay content in the sand [9].

Table 1: Chemical constituents of selected Unilorin dam natural moulding sands

The Elemental Chemical Composition of the Unilorin Dam Natural Moulding Sands (wt.%)		
S/N	**Constituent**	**Weight (%) for Unilorin Dam Sand**
1	SiO_2	58.621
2	V_2O_5	0.108
3	Cr_2O_3	0.030
4	MnO	0.317
5	Fe_2O_3	10.692
6	Co_3O_4	0.034
7	NiO	0.005
8	CuO	0.085
9	Nb_2O_3	0.012
10	MoO_3	0.006
11	WO_3	0.022
12	P_2O_5	0.322
13	SO_3	0.497
14	CaO	2.562
15	MgO	0.000
16	K_2O	9.107
17	BaO	0.586
18	Al_2O_3	14.074
19	Ta_2O_5	0.065
20	TiO_2	1.503
21	ZnO	0.012
22	Ag_2O	0.055
23	Cl	0.809
24	ZrO_2	0.323
25	SnO_2	0.154
		Total = 100.00

However, this absence may have minimal impact on the sand's strength because clay acts as a binder that holds the sand grains together. The Unilorin Dam Natural molding sand, with its 58.621 wt.% Silica content followed by Alumina (Al_2O_3) at 14.074 wt.%, belongs to Alumina silicate class of sand due to its high silica content. Most foundry sands for metal casting are high-quality silica with specific physical characteristics [9].

Although CaO, K_2O, and TiO_2, among others, are oxides of low melting point metals, their presence is considered impurities in molding sand because they can lower the fusion point of the sand, reducing its refractoriness and chemical inertness. According to Table 2 with ranges of acceptable standards for various castings, the slight increase in temperature above room temperature can cause these impurities to react with surrounding gases, leading to defects in the casting when such molding sand is used for foundry applications. The brownish colour of the Unilorin moulding sand, can be attributed to their Iron (III) Oxide content (10.692 wt.%), which turns red when subjected to firing. An excess of Iron (III) Oxide can lower the fusion point considerably, which is undesirable [27]. The Unilorin dam natural moulding sands fall within the acceptable ranges for casting Ferrous and Non-Ferrous metals without the inclusion of additives [9, 24, 25].

Table 2: Satisfactory Mould Sands Properties for various types of Castings [12]

Metal	Clay Content (%)	Moisture Content (%)	Green Compressive Strength (kN/m²)	Dry Compressive Strength (kN/m²)	Permeability No.
Heavy Steel	10 - 12	4 - 5	70 - 85	1000 – 2000	130 – 300
Light Steel	7-12	6 - 8	70 – 85	400 – 1000	125 – 200
Heavy Grey Steel	10 -19	6 – 8	70 – 105	50 – 800	70 – 120
Aluminium	8 - 10	4.5 – 5.5	50 – 70	200 – 550	10 – 30
Brass and Bronze	10 - 15	5 – 7.5	55 – 85	200 – 800	15 – 40
Light Grey Iron	8 - 13	4 - 6	50 – 85	200 – 550	20 – 50
Malleable Iron	8 - 14	5 - 7	45 - 55	210 – 550	20 – 60
Medium Grey Iron	11 - 15	5 - 8	70 - 105	350 – 800	40 – 80

3.2 Physio-Chemical and Structural Properties of Unilorin Dam Moulding Sand

3.2.1 Grain Fineness Number

Table 3 and 4 presented the mechanical properties of the Unilorin dam natural moulding sand and the grain fineness distribution of Unilorin dam natural moulding sand, respectively, obtained from the various experiments conducted

Table 3: Mechanical properties of the Unilorin dam natural moulding sand

S/N	Samples / Properties	Unilorin dam sand
1	Colour	Brown
2	Grain Fineness number	63.91
3	Moisture content (%)	0.73
4	Clay content (%)	4.98
5	Specific gravity	2.56
6	Bulk density (kg/m³)	2306.46
7	Shatter Index (Green) (%)	58.2
8	Shatter Index (Dry) (%)	87.83
9	Green Compressive strength (kN/m²)	87.29
10	Dry compressive strength (kN/m²)	234.02
11	Permeability (cm³/sec)	0.005330
12	Refractoriness	>510°C

As seen in Tables 3 and 4, as well revealed in Figure 1, the Grain Fineness Number (GFN) serves as a quantitative measure of the grain size distribution within a sand sample, as determined through a sand sieve analysis. This distribution has a discernible impact on various properties of the sand, including refractoriness, green strength, dry strength, hot strength, permeability, and compatibility [28]. Permeability, specifically, pertains to the moldability of the sand in relation to gas release. Sand containing a wide array of particle sizes tends to exhibit lower permeability compared to that composed of grains with an average fineness [28]. It is crucial to note that sand that is excessively fine or coarse can have adverse effects on the quality of the resulting castings [12]. Distinct types of sands possess varying GFN values, with each type tailored to specific casting requirements. According to ASTM (American Society for Testing and Materials) standards, the GFN values falls within the range of 35 to 90, rendering it suitable for both medium and heavy metal casting (Shuaib-Babata *et al.,* 2019). When the grain fineness number falls within this range (35 to 90), the sand is considered appropriate for molding purposes

[9], [14]. In the case of the Unilorin Moulding Sand, is GFN at 63.91, aligning it with the specified standard values (35 – 90) for non-ferrous metals. This implies that the sand's average grain size is approximately 210 µm, classifying it as finer, a crucial parameter when selecting sand based on particle size distribution [29, 30]. Fine sand typically yields good surface finishes but may have reduced permeability, potentially resulting in gas defects. The size distribution of the sand notably impacts casting quality.

Table 4: Grain Fineness Distribution of Unilorin dam natural moulding Sand

BS Sieve No	Sieve size(mm)	Weight Retained(g)	% Retained (X)	% Passed	Multiplier (Y)	Product (X x Y)
8	9.5	12.14	1.214	98.79	0.375	0.455
10	4.75	25.1	2.51	96.28	4	10.04
16	2.36	53.56	5.356	90.92	8	42.848
22	1.18	87.5	8.75	82.17	16	140
60	0.6	122.56	12.256	69.91	22	269.63
100	0.3	203.88	20.388	49.53	60	1223.28
150	0.15	189.26	18.926	30.6	100	1892.26
200	0.075	99.54	9.954	20.65	150	1493.1
Total		**793.54**	**79.354**			**5071.613**
GFN= 63.91						

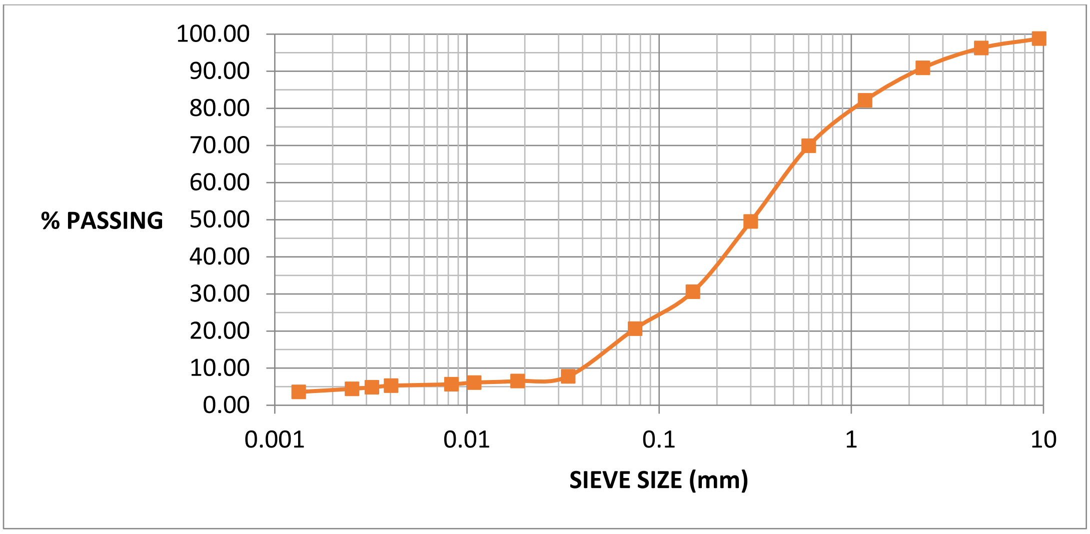

Figure 1: Grain size Distribution of Unilorin dam natural moulding sand

3.2.2 Moisture Content

In the Moulding Sand sample, the percentage of moisture content was found to be 0.68%. The result for the moisture content was very low and not up to standard due to long duration of the sands drying before the experiment was carried out so the sand has lost most of its moisture content, the moisture content can be increased by increasing the water content of the moulding sand. However, the acceptable range is between (4–8%), which is good for casting light steel, heavy grey steel, and medium grey iron etc.[9].

3.2.3 Clay Content

The clay content for the Unilorin dam moulding sand is 4.98%. According to Shuaib-Babata *et al.* (2017), the recommended clay percentage for moulding sand typically ranges from 10% to 12%. However, for castings involving brass, bronze, iron, and steel, American Foundrymen Society typically stipulated that the clay contents are in the range of 12% to 18%. The clay concentration is insufficient for most casting purposes, falling below the recommended range. To meet the minimum clay content requirements necessary for metal casting, an additive (binder) can be introduced, as suggested by Shuaib-Babata & Olumodeji [12].

3.2.4 Specific gravity

The moulding sand with average value of 2.56 falls within the range of the 2.5–2.8 acceptable ASTM standard, indicating that the sand has a high specific gravity and hence has relatively few impurities, which means it won't melt with the cast at higher temperatures. It has been revealed that moulding sand with lower specific gravity

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contains higher impurities and inorganic materials that might melt during the casting process and perhaps cause a casting error [14],[24].

3.2.5 Permeability

The result of permeability test on the Unilorin dam moulding sand sample which is 0.005330 cm/sec. Sand particle size and shape, mould compaction, and the amount of binder utilized in the mould all affect how permeable the mould is. Smaller particles result in a smaller interparticle gap, and it is predicted that the existence of a binder overpass will also limit the permeability of mould. Low permeability leads to flaws like porosity and blow holes. A poor surface finish will result from high permeability also. Therefore, for successful casting, a moderate permeability should be selected [14], [25],[27].

3.2.6 Refractoriness

An Electric Oven was employed to determine the average refractoriness of the sand, which was found to exceed 510°C. Throughout this process, there were no observable alterations in the physical appearance or dimensions of the moulding sand samples, and no signs of fusion on the metal surface were evident. These results indicate that the sand is suitable for casting non-ferrous alloy types with melting points lower than 510 °C or higher. It's worth noting that the temperature can still be elevated to 1200°C with the use of a furnace. Furthermore, the sand can also be employed for certain ferrous alloys that melt below 1,200°C [9].

3.2.7 Green Compressive Strength

The green compressive strength of moulding sand is recorded as 87.29 KN/m^2 for Unilorin sand. This value indicated that the green compressive strength of the moulding sand falls within the recommended standard range of 70-85 KN/m^2 for casting both light and heavy steel, as well as within the range of 70-105 KN/m^2 for casting heavy grey steel. It is worth noting that enhancing the green strength of the moulding sand can be achieved through the addition of a binder, as suggested by Shuaib-Babata *et al.* [9],[25].

3.2.8 Dry Compressive Strength

The Dry compression strength value is 234.02 KN/m^2 with respect to the reference range (200-550 KN/m^2) [12], this result meets the standard requirement for non-ferrous metal. In order to further increase the moulding dry strength, an additive can be added.

3.2.9 Bulk Density

The moisture content of moulding sand directly impacts its bulk density, and optimal bulk density can be achieved by appropriately compacting the sand to release any trapped air within the mould. The Bulk Density value is 2306.46 kg/m^3. It's worth noting that these values fall within the recommended range of 1700 to 2400 kg/cm^3 for refractory bricks, as indicated by Shuaib-Babata *et al.* [9].

3.2.10 Shatter Index

The moulding sand sample's shatter index values is 73.02%. The shatter index of the sand was moderate as too high and too low values of shatter index is often not favourable for the casting. From the shatter index value of the sand, the sand will have a quite low collapsibility value which is a highly desired features in the moulding sand as sands with low collapsibility value tends to prevent free contraction of the casting there by causing tears and cracks in it (Shuaib-babata *et al.,* 2019b). Too high shatter index readings indicate poor moulding quality, which is caused by excessive clay or water content in sand which is not suitable for foundry use [12].

4.0 Conclusion

This study evaluates the suitability of moulding sand obtained from the University of Ilorin Dam for foundry applications. The analysis aimed to identify the strengths and limitations of the sand in practical foundry operations. Results were interpreted to assess its performance that can affect the casting quality, surface finish, and defect minimization. The following conclusions were drawn from this study:

1. The chemical analysis showed that Unilorin moulding sand belong to Alumino-silicate group of sand with chemical compositions within the AFS acceptable range values for moulding sands. Thus, Unilorin dam natural moulding sand is suitable for casting of metals, most especially with low melting temperature.
2. There were presences of some elements such as Calcium oxide (CaO), Iron (iii) oxide (Fe_2O_3), Magnesium oxide (MgO), and Titanium dioxide (TiO_2) apart from the main constituents which most of them serve as impurities. The present of these impurities such as CaO, Potassium oxide (K_2O), and Sodium superoxide (NaO_2) lowers the refractoriness, which may affect the suitability of the sand for casting of ferrous casting, though suitable for non-ferrous casting. Though, these elements were in trace quantities.

3. The results of the physico-mechanical tests falls within and agreed with the AFS recommended values for casting some metals, most especially non-ferrous metals. Therefore, the properties make the sand suitable for metal casting.

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